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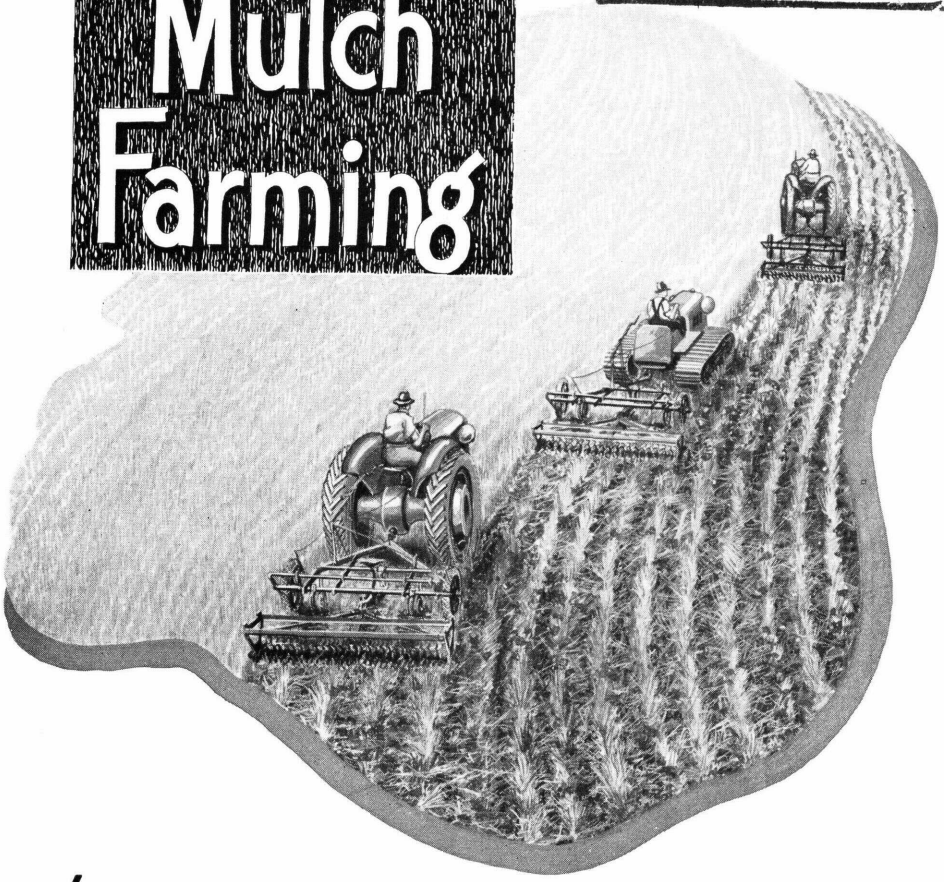
Stubble-Mulch Farming



to HOLD SOIL and WATER

Farmers' Bulletin No. 1997

U. S. DEPARTMENT OF AGRICULTURE

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THIS BULLETIN describes a system of farming in which the residues of the crops grown on the land are used as a mulch to conserve soil and water. Since the residue includes the stubble plus other parts of the crop, this kind of farming has come to be called stubble-mulch farming. Instead of removing, destroying, or plowing under the residue you leave it on the surface of the soil. Thus your fields have a year-round cover.

Used in this way the residue, or stubble, greatly reduces erosion by both water and wind. The stubble mulch keeps wind from getting at the soil to blow it. It also prevents rainfall from compacting the soil. As it decays and becomes humus it improves the soil structure. Thus soil can absorb and hold more water.

In order to leave the dead residue on top, all tillage is done beneath the surface. For this reason it is called subsurface tillage, or—shortened—subtillage.

New methods of tillage are needed for this system of farming. The methods reported in this bulletin were developed at the Nebraska Agricultural Experiment Station at Lincoln, Nebr., with the cooperation of the Soil Conservation Service.

To be effective, stubble-mulch farming requires new implements as well as new methods. Both the methods and the implements are fully described in this bulletin. It also gives practical instructions on how to put a stubble-mulch program in action.

Besides protecting the soil against erosion by wind and water, stubble-mulch farming has proved highly profitable in low-rainfall areas in dry years. In fact, the records for a period of three dry years, with corn, when stubble mulch was retained and subtilled, have shown a 60-percent increase in crop production over that obtained with the usual method of plowing under all crop residues. In wet years there is little or no increase, and sometimes a decrease, in crop production. The gain you get from stubble mulching in wet years comes from the protection against erosion and the assurance that the fertility of your soil is constantly increasing. You should remember, however, that stubble-mulch farming is most effective when used with other well-proved soil conservation practices, such as adapted crop rotations, contour farming, terracing, and grassed waterways.

This bulletin supersedes Farmers' Bulletin No. 1917, Stubble-Mulch Farming for Soil Defense, and Miscellaneous Publication No. 494, Using Crop Residues for Soil Defense.

Washington, D. C. Issued June 1948

STUBBLE-MULCH FARMING TO HOLD SOIL AND WATER[1]

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WHAT IS STUBBLE-MULCH FARMING

MULCHES OF LEAVES, straw, and other organic material have long been used around orchard plants and with some truck crops. These have usually been heavy mulches, often several inches deep. The Chinese have used pebble mulches on some of their dry-land soils for many years. These pebbles allow the water to pass down through the mulch and trickle into the soil. The pebbles reduce evaporation by shading the soil. They also reduce the amount of soil carried away by water or wind erosion. Paper mulches have been used extensively in Hawaii to reduce erosion, runoff, and evaporation on pineapple land.

When the American pioneer removed the forest cover or broke the prairie sod, he began to lose his soil by erosion. Many of the men who removed the original plant cover lived to see the soil so badly eroded that their land had to be taken out of cultivation and replanted to grass or hay crops.

In the original forest the heavy mulch of leaves and other organic matter formed such a protective cover over the soil that most of the rainfall was rapidly absorbed and little erosion took place. Likewise,

[1] This report developed through cooperation of the Soil Conservation Service, Research, United States Department of Agriculture, and the Nebraska Agricultural Experiment Station.

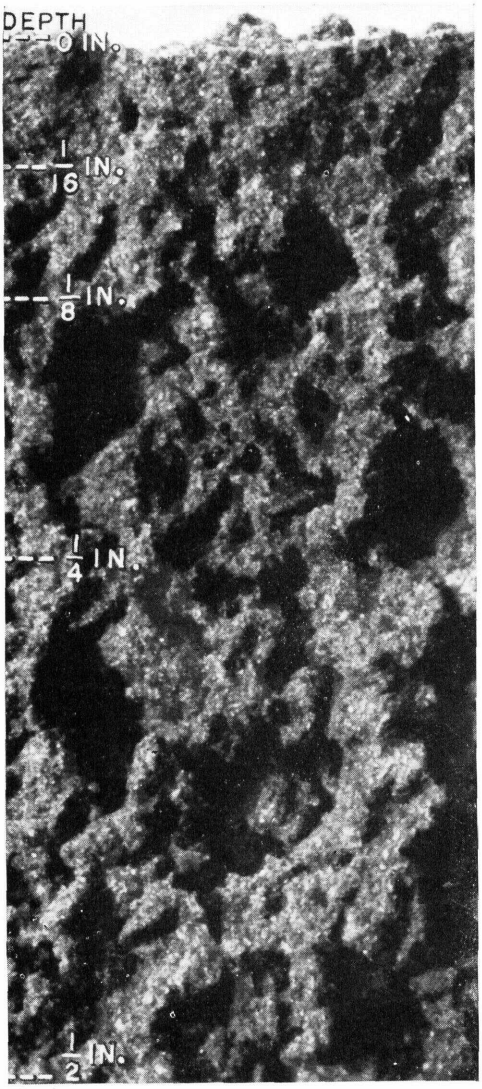

FIGURE 1.—Bare soil, ½ inch thick, on which rain has fallen. Raindrops have destroyed the structure at the surface and compacted a layer about 1/16 inch thick. This thin layer is slick on top and does not let water pass through it rapidly. Much of the water runs off after this compact layer forms.

on the prairies the dense turf with its accompanying organic matter took in water and held the soil in place even during the heaviest rains. The pioneers saw that the forest floor and the unbroken prairie sod held moisture and stopped soil washing; yet they did not seem to think of using the same principle on a large scale to keep their fields from washing. Consequently, most of the farming in this country was and still is being done under a system of clean tillage.

But there is another method of tillage that many farmers are now using. Because all the tillage is done beneath the surface it is known as *subsurface tillage*. Instead of burying the dead residue of the previous crop, subsurface tillage leaves it on top of the soil. The crop residue, made up of the stubble plus other parts of the previous crop, forms a mulch—a "stubble mulch"—that protects the land. Thus this system of farming has come to be called stubble-mulch farming.

EFFECT ON INTAKE OF WATER BY SOILS

Water enters a soil during rains through the pores or spaces between the soil granules. As long as these pores are open, water may soak into the soil at a fairly rapid rate until the soil is so filled as to

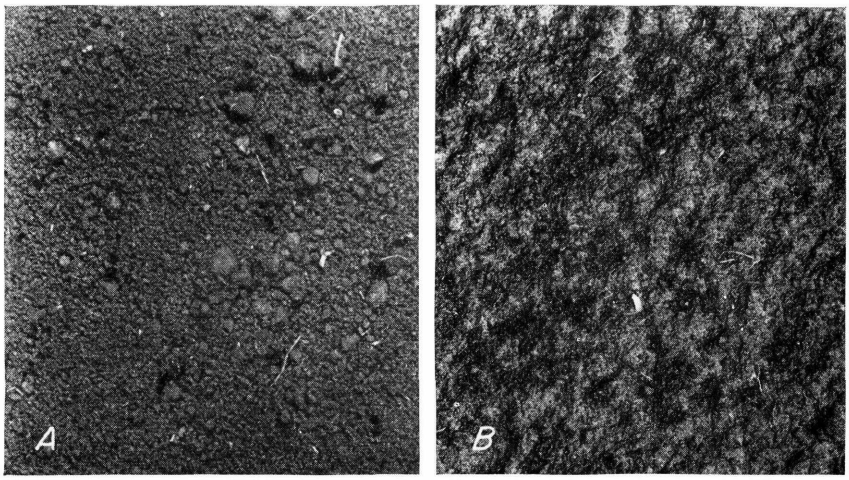

FIGURE 2.—*A*, This is a well pulverized, open soil; *B*, the same soil after the surface has been compacted by rain so that water does not enter it readily but runs off.

slow down further absorption. But if these pores at the surface become clogged up or sealed over, the water cannot soak in rapidly. If the land is bare so that the raindrops strike it directly, the soil granules are broken and the fine mud forms a seal over the surface, making the soil look slick on top. In this condition the soil will take water very slowly and much of the water will run off during a heavy rain (figs. 1 and 2).

In order to prevent a surface seal from forming, the raindrops of a heavy rain must be kept from hitting the bare soil directly. Prevention occurs naturally in a forest, where the soil is covered with a thick layer of decaying leaves, or in well-sodded grassland.

Any plant cover, such as a growing field crop, tends to do this also, but too often, or at certain stages, all the ground is not covered. When you cover the soil with some sort of crop residue, such as small grain stubble and straw, corn or sorghum stalks, litter from other crops, or even dead weeds, you keep the raindrops from striking the ground and from puddling the surface. You thus enable the soil to retain its high capacity to absorb water.

If soil is cloddy or roughly plowed, these clods or chunks act as protection to soil below. The intake of water may be high on roughly plowed land until the clods slake down and the surface becomes smooth.

EFFECT ON EROSION

Growing plants form effective protection for the soil against erosion to the extent that they cover the surface. Land covered with dense forest or a luxuriant growth of grass is well protected from rain and wind. Even though there may be some runoff, the water runs so

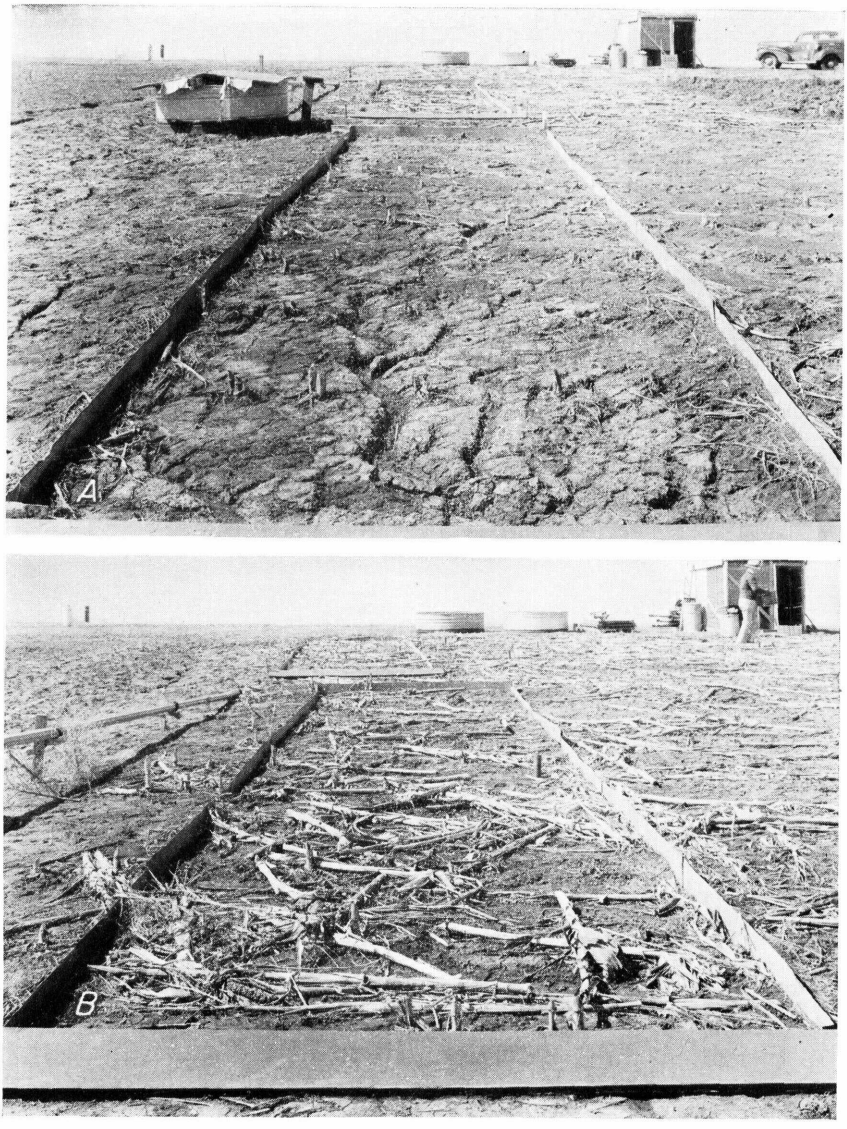

FIGURE 3.—Plots on 5-percent slope that received 9.78 inches of rain: *A*, Where cornstalks had been removed the soil lost 1.95 inches of runoff and 10.14 tons of soil per acre; *B*, where cornstalks were left on the land the soil lost 0.51 inch of runoff and 0.54 ton of soil. In short, the bare land lost nearly 4 times as much water and 19 times as much soil as that with a mulch of cornstalks.

quietly through this debris or over the sod that it does not pick up or move the soil. On bare soil the raindrops splash the mud, and once the soil particles are broken loose they can be carried by moving water.

Where there are no growing plants, you can use the dead plants and crop residue to protect the soil against erosion. Small-grain stubble will protect soil against serious erosion, particularly if the grain has been combined. Little erosion will take place on such land until it has been worked and some or all of the surface is bare. When you break cornstalks down on the land they will also form a protective covering for the soil (fig. 3). But if you pasture them heavily they lose much of their protective power. You will find that other crop residues and even weeds can be used to protect the soil. Strawy manure or other debris will also reduce runoff and erosion.

Wind erosion is much less on soil covered with vegetation or crop residue than on bare soil. Such residue greatly reduces the velocity of the wind at the ground surface. Furthermore, the residue prevents the wind from striking the ground directly, and therefore keeps it from picking up much soil. If you have a fairly dense cover on the land and some of the residue is attached to the ground, soil blowing will not be severe. Many farmers have been able to maintain enough wheat straw on their land to prevent wind erosion.

EFFECT ON SOIL-MOISTURE STORAGE

In regions of low rainfall it is important to store moisture in the soil for the use of the next crop. Some farmers in these regions keep the land fallow during a part or even a whole season in order to store moisture in the soil. This is usually done by plowing the land and then cultivating to keep down weeds.

Experiments have shown that you must do the following things to store a large part of the rainfall in the soil: (1) Reduce loss of water by runoff, especially during heavy rains; (2) reduce evaporation losses; and (3) keep weeds from using the soil moisture.

Farmers who fallowed land by plowing and worked it later to kill weeds have often failed to a great extent in the first two of these. You can accomplish all of these things with subsurface tillage under a mulch. By keeping residue on the surface you can reduce runoff and decrease evaporation. And by working the soil beneath the residue you can also control the weeds.

It is important that you have enough residue on the land so that the rainfall can soak in and there will be little or no runoff. In many dry-land regions occasional heavy rains occur. If you can save the water from the heavy rains you may get water to soak into the ground below the surface 6 to 12 inches where it will be protected from evaporation. Since small showers during summer wet the soil down only a few inches, most of the water is lost by evaporation.

Tests have been made to determine which methods of fallowing are best to conserve moisture. It has been found that crop residue on the surface increases the intake of water and reduces evaporation. Such residue also reduces evaporation greatly during winter and early spring. Stubble mulching has proved to be one of the simplest and most effective methods of fallowing land. By this method you can reduce erosion by either water or wind as compared with bare fallow. Table 1 shows how stubble mulch and subtillage can help store water.

TABLE 1.—*Effect of straw mulch on the amount of moisture stored in uncropped land to a depth of 6 feet during the summer months (April to September, 1938–41)*

Treatment	Tillage	Rainfall stored	
		1938–41	1939–41
		Inches	*Inches*
No straw	Disked	1. 03	0. 21
No straw	Basin-listed	2. 28	1. 39
2 tons straw	Plowed	1. 84	. 41
2 tons straw	Disked	1. 96	. 30
2 tons straw	Subtilled	3. 78	1. 80
4 tons straw	Subtilled	-------	2. 80
8 tons straw	Subtilled	-------	4. 21

In dry years it is important to make use of any heavy rain that may come. If you can eliminate most of the runoff at such a time you will have water stored at greater depth, possibly in the second, third, or fourth foot of the soil, where it can be used by plants with much less loss from surface evaporation. Later in the season, you can make good use of water that was stored in late winter or early spring. It often happens in the Great Plains that you can carry a corn crop through a dry July largely on water stored from snow the previous winter.

In much of the subhumid and semiarid country it is difficult to get enough water into the ground to moisten the deep subsoil. This greatly hinders the production of deep-rooted crops like alfalfa or orchard trees. Any system of conservation by which you can help replenish the moisture in the deep subsoil will be well worth while.

KEEPING A MULCH ON CROPPED LAND

The term "stubble mulch" is used to indicate various types of residue. It may refer to the actual stubble from a crop such as small grain, or it may refer to both stubble and straw as on a combined wheatfield (fig. 4). It may refer to cornstalk or sorghum residue, soybean straw, cotton stalks, sudan stubble, weeds, or any other material produced on the land and used to cover the surface of the soil.

The amount of residue or mulch present will usually be only that produced by the previous crop. Not much residue is apt to be carried

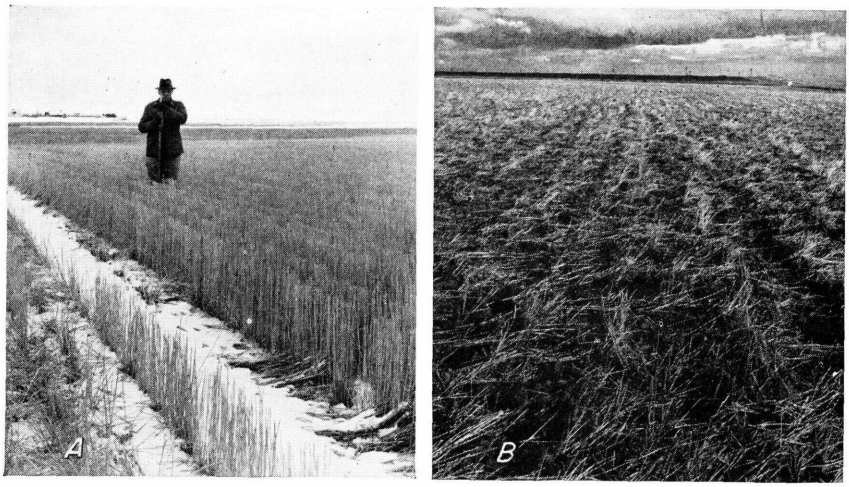

FIGURE 4.—*A*, Heavy residue of combine wheat stubble being carried through the winter on the Plains of western Nebraska; *B*, heavy wheat residue that has been tilled with a one-way disk plow to kill volunteer grain. Land with this much residue cover is well protected against wind erosion.

over into the second year throughout the central and southern parts of the United States. In the Northern States and Canada, decay is slower, and where residue is heavy some may be carried over into the second year. The quantity of residue will range from less than 1 to more than 3 tons per acre.

When you adopt stubble mulching, it is important that you plan to grow crops each year that will provide enough residue to hold the soil until the next crop is large enough to protect the land. Then, too, you can vary the method of tillage in such a way as to hasten or retard the decay of residue. In some cases where the amount of residue is light, some care on your part will prevent this small amount of residue from decaying so completely as to lose its protective effect. On the other hand, where you have more residue than is needed, some mixing of the material with the soil during tillage will hasten decay and thus reduce the amount on the surface. Your main object should be to handle the residue in such a way that there will be about the desired amount present when the next crop is planted. There is probably no definite amount that would be best in all cases. If you have too little, it may not protect the soil satisfactorily against runoff and erosion. If you leave too much it may sometimes keep the soil too cool or too wet for the best crop production.

Remember that you need to provide mulch in amounts that will not interfere with crop production but that, along with the growing crop, will protect the soil against excessive runoff and erosion.

For your convenience in tillage operations be sure to distribute all residue as evenly over the field as possible. Use straw spreaders with

your combine harvesters. You may also need to cut corn or sorghum with stalk cutters. In using disk harrows or one-way disks to cut up residues you should operate them so that they do not penetrate deeply or bury too much residue. Buried residue does not give protection to the surface; it decays too rapidly and when tough interferes with the operation of other tillage tools.

SUBSURFACE TILLAGE

In order to farm land while keeping it covered with residue you will have to break up the surface soil and pulverize it without turning it completely over. For best plant growth you need to pulverize the soil so that air can penetrate it freely and thus furnish oxygen to the growing plants and soil micro-organisms.

You can use many different types of equipment to cultivate the soil without turning it completely over. Most of the primitive-type plows used in many foreign countries do not turn the soil completely over. But the steel plow, with its carefully curved moldboard, does this job of turning more thoroughly. One of the first tools tested in this country for tilling the soil without inverting it was simply a plow with the moldboard removed. Another was a plow with a part of its moldboard cut away. These covered part of the residue and left part of it sticking out of the plowed surface.

TYPES OF SUBSURFACE TILLERS

Recently, implements have been devised for running under the surface of the soil at depths of 2 to 6 inches. These loosen the soil without turning it over and without burying the residue. Since these implements work beneath the surface, they have been designated by the general term "subsurface tillers" or, shortened, "subtillers." They derive their pulverizing action from a blade that lifts the soil slightly as it moves up and over the blade. There is some crumpling and shearing of the soil at the forward edge of the blade. As the soil drops down behind the blade it is broken further and partly pulverized. If the soil is in proper condition, it will be pulverized and loosened very much as if it had been plowed. These implements are of three principal types: (1) tillers with V-shaped sweeps, (2) straight-blade tillers, and (3) rod-weeder tillers.

Tillers With V-Shaped Sweeps

The subtillers with V-shaped sweeps carry sweeps that range in cutting width from 15 inches to 8 feet or more (fig. 5). For working through ordinary amounts of residue a minimum width of 24 inches is desirable. There should be a clearance between the sweep and the beam of at least 18 inches. Some of the most popular machines have sweeps about 30 inches wide. They are usually constructed with

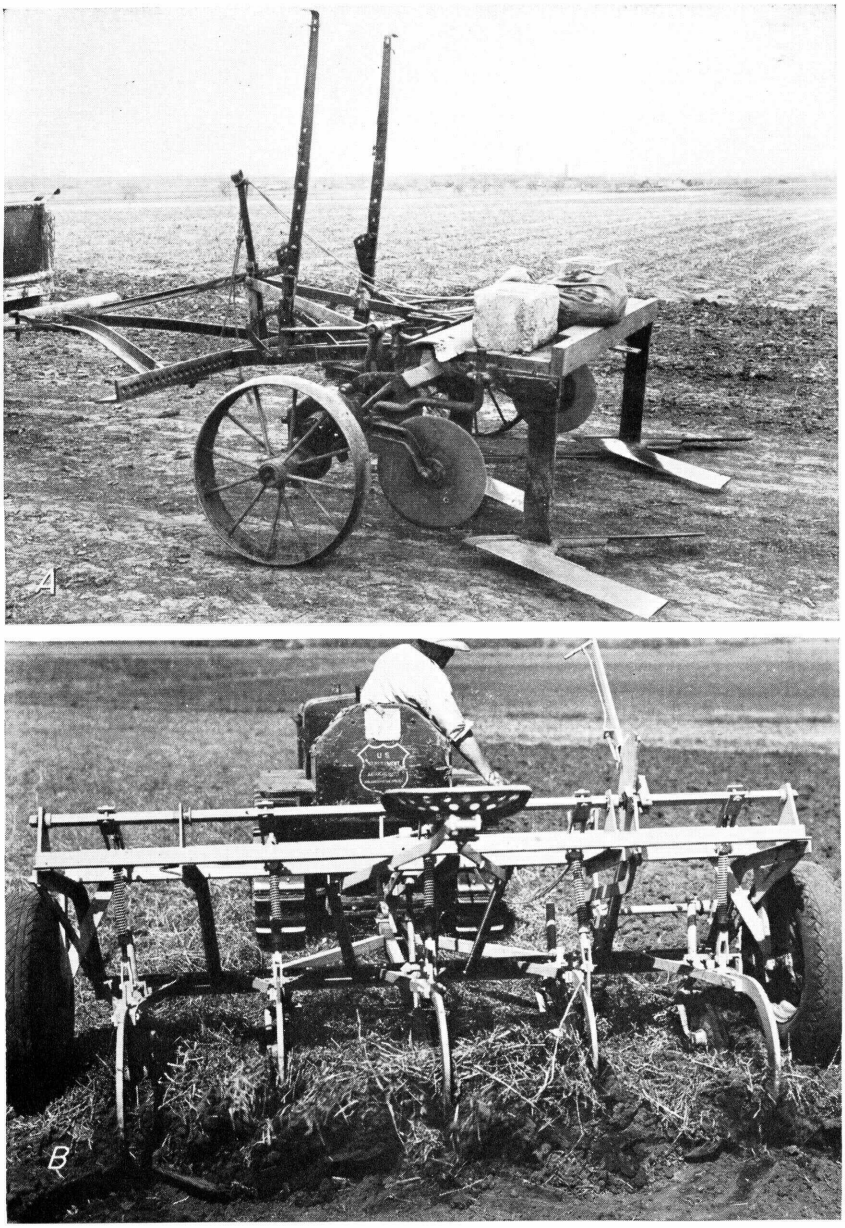

FIGURE 5.—*A*, A subsurface tiller with 31-inch sweeps. Because of the clearance beneath the frame, this tiller can be operated through very heavy residue or plant growth without clogging. *B*, A subsurface tiller with five 22-inch sweeps. Rolling coulters ahead of each shank cut through the residue and prevent clogging.

V-angles ranging from 60 to 90 degrees. Three such sweeps on one machine will cut about 7 feet—or the width of two corn rows—and make a good load for many of the larger farm tractors.

Machines with sweeps 4 to 5 feet wide have one or two on the machine. Sweeps of 5 feet or more usually have a V-angle of 85 to 100 degrees.

The construction of the V-blade is of great importance. Most of the blades have been made of flat 4-inch steel. This is drawn to a thin edge along the cutting side. Some blades are made of curved steel. In some the concave side is on top and in others the convex side is up. The convex side has been placed up on some machines in an attempt to make the blade self-sharpening, but this has been only partly successful. Sweeps with the convex side up, however, give good pulverizing action on the soil. They also have more suction and tend to pull themselves into the ground more than do the flat blades or blades with the concave side up. Sweeps can be sharpened a few times by grinding but then must be rehammered to a thin cutting edge. They must be kept sharp in order to penetrate the soil easily. With sweeps of flat steel the V-point should be turned down slightly to give the sweep more suction. This is especially necessary where the ground is too dry for best work.

Rolling coulters placed ahead of the standards for the V-sweeps should always be used where there is any amount of residue. They aid greatly in clearing trash and help prevent clogging on the standards. Coulters at least 15 inches in diameter are the most satisfactory. They may be either smooth or notched.

Straight-Blade Tillers

The straight-blade subtillage tool has been used extensively in Canada and parts of northwestern United States. It consists of a straight cutting blade 6 to 7 inches wide and 5 to 12 feet long. The blade may be flat or curved. The curved blades are more effective in pulverizing the soil and tend to be self sharpening. One machine is so designed that two large V-sweeps, 4 to 5 feet across, can be used interchangeably with the straight blade. Straight blades are mounted on a heavy chassis and are so strongly built that they will withstand very rough treatment. If the blade hits a rock, either the machine will jump out of the ground or an emergency pin on the hitch will break and release the tractor.

Rod-Weeder Tillers

A third type of subtillage machine is the revolving rod weeder. The simple rod weeder has been used in the Great Plains and the Prairie Provinces of Canada for many years. It was usually used simply as a weeder after plowing, by running the revolving rod 1 to 2 inches below the surface. To convert this implement into a subsurface tiller,

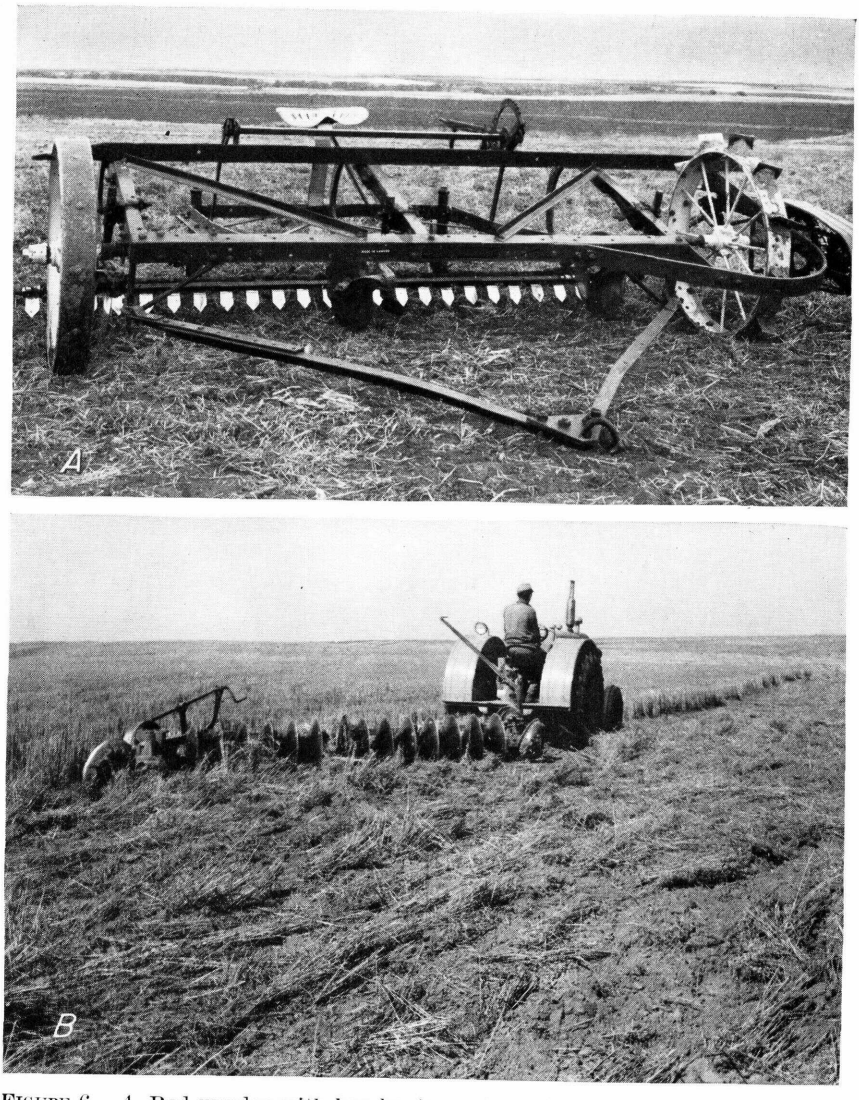

FIGURE 6.—*A*, Rod weeder with bar having points attached below revolving rod. The rolling coulters attached to the frame ahead of each curved beam aid in clearing trash. *B*, A one-way disk. You can often use this implement to advantage for the first operation in preparing stubble-mulch land. But if you use it for all fallow operations, it will generally bury the straw so completely that there will not be enough left on the surface to prevent serious wind erosion.

a bar carrying narrow teeth, or small shovels, was attached below the revolving rod (fig. 6, *A*). When thus equipped the machine will penetrate soils in plow condition. It will pass through considerable residue without great trouble from clogging. However, if the amount of residue is more than 2 tons per acre of small-grain stubble and straw

or its equivalent, the rod-weeder does not clear trash as well as the V-sweep machine. Using rolling coulters ahead of each goose-neck standard will aid in clearing trash, but this does not completely eliminate the trouble.

This modified rod weeder is particularly effective at weed eradication after the soil has been tilled once with a heavier tool such as a V-sweep machine. It pulverizes the soil well but does not leave it too fine as is often the case with disk tools.

THE ONE-WAY DISK

The one-way disk can sometimes be used to advantage along with other subsurface tillers. This implement has been used extensively in the Great Plains in preparing land for wheat. It will go through mulch with little trouble from clogging and it kills the volunteer crop (fig. 6, *B*). But it does cover part of the residue. If the angle of the machine is adjusted so that the disks do not throw too much soil, only small amounts of straw will be covered in one operation. If used again to kill weeds, however, the residue may be buried almost completely. For this reason the one-way disk is not suited for an entire fallowing job. Usually it should be used only for the first operation through heavy residue to kill the volunteer crop.

In some cases the ordinary disk harrow may be used on heavy residue for the first operation. It will chop up the straw so that other subtillage implements can be used. It may be necessary to put extra weight on the disk or to cut the land twice if the straw is very heavy.

Other subtillage tools that bury less straw should be used at later operations after both the one-way disk and the disk harrow.

SOIL REQUIREMENTS

Subsurface tillers, like plows, operate most satisfactorily in sandy loam, silt loam, or silty clay loam soils. In heavier (more clayey) soils you must take more care to till the land when it is neither too wet nor too dry. On very heavy clay soils or gumbo spots it is hard to break down the soil fine enough with subsurface tillers except under the most favorable moisture conditions. Of course, it is also difficult to handle such soils with moldboard plows. Disk-type tools are better for such heavy soils, but care must be taken not to bury all the residue if a disk plow or one-way is used.

Subsurface tillers do their best work when the soil moisture is about right for good plowing, or slightly drier. If the soil is dry, most weeds will be destroyed. If the soil is too wet it will tend to hang together as its comes back over the sweeps or blades. In that case it may not be shaken loose from the roots of the weeds and they will continue to grow. If this should happen the land must be tilled again with some type of weeder.

Subtilling should not be done when you are expecting rain within 24 to 48 hours. Weeds are killed by undercutting with these machines. If rains come soon after the tillage, the weeds are apt to take root again. Hence, subtillage is usually most successful when done during a short period of dry weather. For the same reasons, tillage should not be done soon after a rain. It may often be advisable to delay operations for a half day or a day to let the soil dry out. Weed eradication will be more effective if you do this.

TREATMENT OF RESIDUE

You need no special treatment before subtilling residue that is fairly short, such as small-grain stubble and straw. Cornstalks, where row crops are to be planted, are usually cut or broken most easily while the ground is firm. The subtillage can then be done afterward. You can subtill cornland in the fall right through the standing stalks (fig. 7). Tall, dry residue like old, dry sweetclover or large weeds can be broken down and partly pulverized ahead of the tiller. By doing this you make it easier to plant and cultivate the following crop. Any residue such as manure, straw, corncobs, or trash that is to be applied to land should be put on before subtillage.

DEPTH OF SUBTILLAGE

You should subtill land at about the same depth that you plow or disk it. When preparing land for a crop like corn or other row crop, you should subtill it 5 to 6 inches deep. This gives a deep, well-aerated seedbed. In completing the seedbed preparation, any later tillage for weed eradication should be at about the depth of disking—2 to 3 inches.

In preparing land for wheat you should go at least 4 to 5 inches deep in one of the tillage operations. The operations for killing weeds should be as shallow as possible. This will usually be about 2 inches. Operations for weeding and packing will be discussed later under treaders (pp. 18–21).

Subsurface tillers usually run more smoothly if you put 200 to 400 pounds of extra weight on the machine. They also penetrate the ground more readily. If the ground is dry, additional weight on the machine will improve the penetration and smoothness of operation.

FALLOWING

In fallowing land for a full season the subsurface tiller may be used to advantage for one or more of the operations. It should be used once for the deep working of the soil. Other operations, primarily for killing weeds, may be done in part by shallow subtillage.

Where the residue from the previous crop is exceptionally heavy (fig. 4), it may be advisable to go over the land the first time with a

one-way disk. This cuts the straw and mixes some of it with the soil so that decay goes on rapidly. If there are low places in the field where straw is down and very heavy, it may be necessary to go over this part of the field more than once to get the straw chopped and mixed with the soil. If the second operation is with a subtiller, you can loosen the soil to the depth desired. You may then get rid of the weeds by shallow tillage with either the subtiller, the rod weeder, the weeder with shovel attachment as already described (fig. 6, *A*), or by means of a combination **V**-sweep and rod-weeder machine. The rod weeder also serves as a packer, and wheatland fallowed by this method is usually firm enough for seeding. If it is not, the packer or treader may be used.

TIME FOR WORKING RESIDUE

In preparing land for spring small grains you can protect it against runoff and erosion by using stubble mulch. You should work the residue well down so that drilling can be done efficiently. If you care to follow a row crop with small grain it is often a good plan to give one tillage in the fall. This allows water from snow to enter the soil more readily and therefore reduces runoff. It likewise encourages earlier drying in spring so that usually you can get your seeding done a few days earlier than on land with no fall working. You should cut heavy stalks with a stalk cutter or disk. Then you can work the land with a disk or a subtiller so that most of the residue will be left on the surface.

In preparing land for row crops, you will need to do most of the tillage in the spring. Usually, it is best to delay tillage until a crop of weeds can be killed. As this period before planting may be fairly long, there is usually a chance to do this in good time, except during very wet, cold springs. The more northern parts of the country and the areas of high rainfall have more trouble with weed eradication than the lower rainfall sections of the Corn Belt or the Central and Southern Great Plains.

Subsurface tillage in summer usually is done to prepare land for a fall-seeded crop or to kill weeds before a spring crop. If you till stubble land for a fall-seeded crop, it is usually good practice to give one tillage as soon as the previous crop is harvested. Thus you will get the tillage done before the soil dries out and becomes too hard to till. You will also cover shattered grain and hasten its sprouting. When it comes up you can kill it before time to seed the fall crop. You can do this tillage with a disk, a one-way, or a subtiller. By pulling a treader behind the tillage implement (fig. 9, *A*), you can do a more effective job of planting the shattered grain. This is important whether you are to seed fall grain, alfalfa, or grass.

FIGURE 7.—Subtilling land that has a heavy crop of cornstalks. If the sweeps are run below the main clump of roots, the stalks do not interfere with their action.

FIGURE 8.—Condition of soil after fall subtillage. Note how soil has been pulverized and also how the corn root systems are lifted out of the ground.

In many cases stubble fields grow up to weeds in late summer or early fall. It is important that such weeds shall not produce seed where stubble-mulch farming is being practiced regularly. Your first step in weed control under this system is to prevent weed seed from maturing. Therefore, if weeds start on stubble or wasteland, you should subtill the ground before the seeds mature. The vegetative part of the weeds will then form valuable residue to protect the soil. If the ground should be so dry that subtillage is too difficult, you can mow the weeds and subtill the land when moisture conditions are more favorable.

In some cases it is good practice to subtill the land or to plow it with a one-way disk in the fall as part preparation for spring crops. You can subtill cornland from the time the corn has been husked until freezing weather prohibits further field work (fig. 7). Tillers work satisfactorily through cornstalks and leave the land in a loose condition through the winter (fig. 8). Water from snow is absorbed more readily, and less water is lost if snow melts while the ground is frozen. The soil also dries out earlier in spring. As already stated, you can often seed a crop like oats several days earlier on fall-subtilled land than on land where no tillage was done until spring. By fall subtillage of combined soybean land you may greatly reduce erosion and loss of water from melting snow.

TREADERS

When preparing a seedbed with subsurface tillers, you will find that several operations are usually needed. You may need to break the residues in advance of tillage and to smooth or pack the ground afterward. Then you must also get rid of the weeds on the subtilled land.

If you were using a moldboard plow, you would later have to use disks, harrows, and packers. On subsurface tilled land you can usually accomplish all of these smoothing operations with a single implement called a "treader." A treader is made by reversing the pronged wheels on a certain type of rotary hoe. It does more packing than cultivating but breaks clods and exposes the roots of small weeds. There are various ways in which you can use this tool. In many cases you can use it in combination with a disk, stalk cutter, or other implement (fig. 9).

To prevent small-grain ground from getting too hard to work after harvest it is a good plan to subsurface-till or disk immediately behind the binder or combine. The subsurface tiller does best if it is run with the treader hitched behind (fig. 9, *A*). By this tandem operation you will not only conserve the moisture in the surface layer of soil, but you will also plant the shattered grain so that it will germinate immediately or after the first good shower.

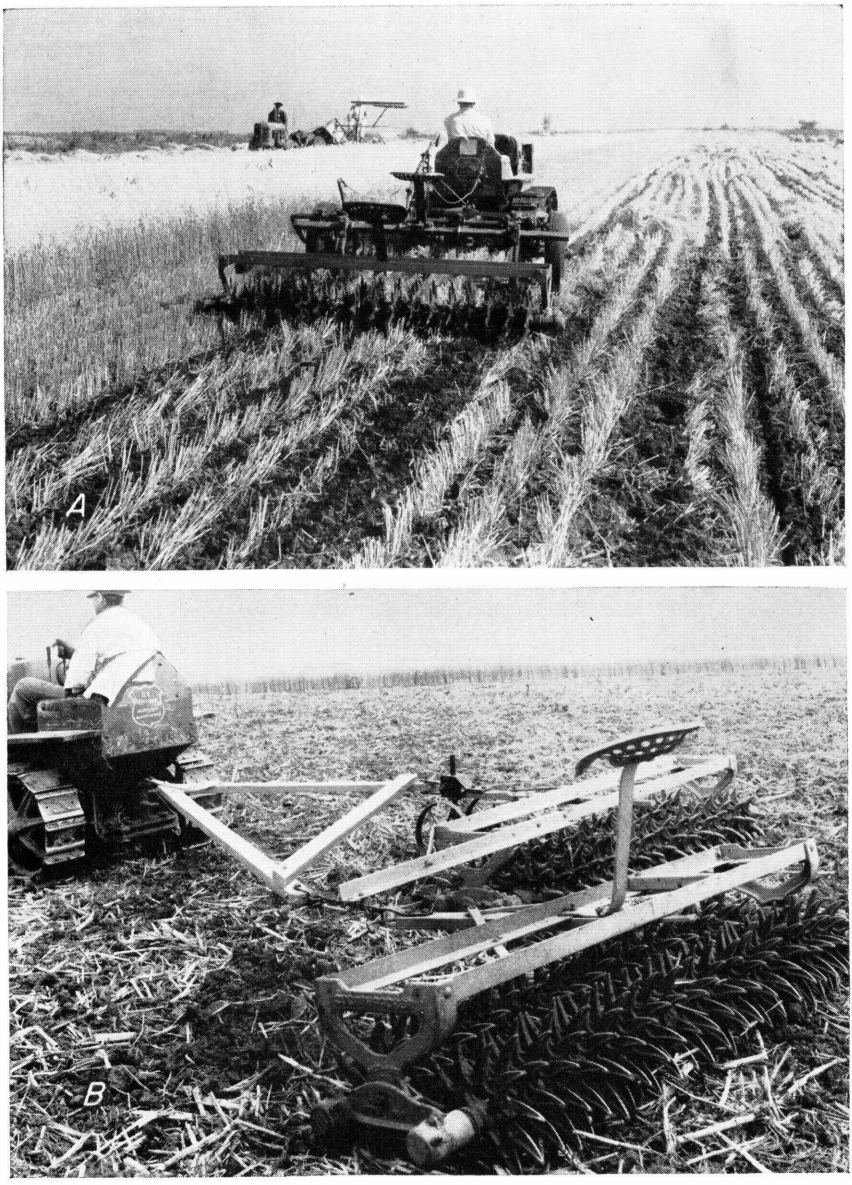

FIGURE 9.—*A*, A subtiller with treader behind, following the binder. This gives a tillage before the ground gets hard. Volunteer plants from the shattered grain come up quickly and can be killed by later tillage. *B*, You can pull two treaders with a triangle hitch. By doing this you can make turns either to right or left.

Use as a Packer

On loose, subsurface-tilled land the pronged wheels of a treader penetrate through the residues and pack the soil from the bottom upwards, making a firm connection between surface soil and subsoil. Bunches of residue on the surface are loosened and spread, and the ground beneath the residue is smoothed. The residues are pushed into the ground very little and are not buried. This packing is usually necessary before small grain is planted, in order to give a firm seedbed. If you have a drill and a treader that are the same width, you can hitch the treader behind the tractor and the drill behind the treader. Thus, you can do the packing and seeding at one operation.

Packing is not ordinarily considered necessary before planting row crops. However, where you have abundant residue you can do a smoother job of planting if the land is treaded first, and the residue interferes less with later cultivation.

As a rule, subsurface-tilled land should be treaded twice when it is to be seeded to alfalfa, sweetclover, or grasses, because these crops require very firm seedbeds. If you have two treaders you can hitch one behind the other and do the double-treading at one operation.

In many cases you will want a shallow subtillage after a deep subtillage. In order to do this the soil must be firm. By treading the land ahead of the shallow tillage, or pulling the treader ahead of the tiller you can do the shallow tillage with little trouble from clogging.

Use as a Pulverizer

Ordinarily, hard, dry clods are not a problem on subsuface-tilled land. There are times, however, especially in the spring, when subsurface-tilled soil may come up in chunks or slabs. When your land is in this condition, use a treader immediately to shatter the lumps before they become dry. Use it in much the same way as you would use a harrow on freshly plowed land.

Soil seldom crusts after rains on subsurface-tilled land if residues are plentiful. Occasionally, however, freshly planted row-crop land will become crusted along the bare edges of the furrows. A treader can be used to break such a crust just as a harrow would be used if there were no residue to interfere.

Use in Killing Weeds

There will be times after subsurface tillage, when weeds and volunteer grain may not die as rapidly as you would wish. At such times, a treading often will complete the kill better than almost any other operation. The pronged wheels will pulverize the lumps of soil in which weeds find moisture and will tear loose the root systems and expose them to the air. A light disking after subtillage may also be effective in completing the kill of weeds or volunteer grain.

Skew Treading

The weeding action of a treader is much improved when it is pulled obliquely. If you have two treaders, you can hitch one behind the other. Then, turn them so that they are about 2 feet closer together at one end than at the other and tie them in this position with a chain. Thus you can make the side draft of one neutralize that of the other. The pulling of treaders in oblique position is called "skew treading." Since machines now on the market were not designed to be pulled askew, there may be excessive wear on the bearings unless you keep them heavily lubricated. If you use the machines for skew treading only when a particularly difficult job of weeding is to be done, the wear may not be great. But because wear does take place, you should insert extra washers when necessary between the wheels and at the end bearings.

Breaking Dry Residues

Residues that are so coarse or bushy that they interfere with the operation of a subsurface tiller can be broken and pulverized, when dry, with a treader. You can put land with cornstalks, sorghum stalks, second-year sweetclover residue, or weed growth in shape for good tillage by this method. If the material is excessively heavy, you can use a disk, or the treader and disk together. Sometimes either of these machines may be pulled behind a stalk cutter with good results.

Multiple Treaders

Since the draft of treaders is not high, a tractor which will pull a tiller will handle two treaders without difficulty. If you pull them on a triangle hitch, as shown in figure 9, *B*, you can make turns in either direction.

PLANTING CROPS ON STUBBLE-MULCH LAND

Where land has been prepared for planting by the use of subsurface tillers and treaders, you should plant through the residue and leave it on the surface. This requires drills or planters that will work through the residue and into the soil without unduly covering the residue or leaving it where it may interfere with germination or the growth of the plants.

Small-Grain Seeding

A good seedbed for small grain in a stubble-mulch system should be well tilled and firm and have enough residue on the surface to protect the soil. You can achieve this condition by the proper use of one-ways, subsurface tillers, rod weeders, and treaders already described. You should drill the wheat in such a way that a clean furrow down to moist soil will be provided as a place for depositing the seed. No straw should fall back into the row and prevent contact of the seed with

FIGURE 10.—*A*, Drilling wheat through residue with semideep-furrow drill, having 10-inch row spacing; *B*, drilling wheat on light oats residue with press drill behind treader.

moist soil. Considerable residue, however, should be left on the surface between the rows. This will reduce runoff and erosion until the wheat is large enough to protect the land.

You may plant with standard drills that make rows 7 to 8 inches apart. These may cause some trouble from clogging, however, if

there is very much residue on the surface. Also, there is a tendency for these drills to allow straw to fall into the row and become mixed with the seed. The semideep-furrow drill, which has a row spacing of 10 inches, will clog less and you will find drilling easier than with narrow-spaced drills (fig. 10, *A*).

The deep-furrow drill, which usually has a 14-inch spacing, has been widely used in many parts of the Great Plains. You can operate it through large amounts of residue without clogging, and you can usually put the furrows down to moist soil so that germination is favored.

Another drill that has been used in many experimental tests on drilling wheat through residues is the low-down, press-wheel drill. This drill has flat disks that are set at a slight angle and operate like rolling coulters. A narrow furrow is made by a small shoe which fits against the disk. This drill has 10-inch row spacings and will pass through large amounts of residue with very little trouble from clogging. The residue is held out of the row furrows by means of strap-iron fingers that are attached to the shoes. These fingers are long enough to wipe the residue out until the press wheel can press the soil over the seed. It is important that the straw should not become mixed with the seed, since wet weather might affect germination, and dry weather might cause the soil to dry out next to the seed.

In order that the soil may be as firm as desired, it is often good practice to pull the drill behind a treader (fig. 10, *B*).

Seeding Legumes and Grasses

Small-seeded legumes, like alfalfa and clover, or grasses most commonly are sown on fine, firm seedbeds free of all vegetation. If a dashing rain comes before the plants are well started, the soil surface may be greatly cut by a network of small rills (fig. 11). The bottoms of these rills are then free of vegetation and may continue to wash out and deepen, often developing into large gullies as the stand gets older. The condition may become so serious as to make it difficult to run a mower or other harvesting machine over the field.

In order to prevent this erosion during the period following seeding, it has been found practical to keep the surface covered with residue and do the seeding through this. You can prepare the seedbed by subsurface tillage followed by treading. You can do the seeding with a grain drill that has a seeder attachment. A lime spreader with double agitator has been found satisfactory for seeding brome or other light-seeded grasses on firmly packed soil. The treader is then a good tool to cover the seed and pack the ground (fig. 12, *A*). Your small-seeded crops can be planted with a grass seeder attached to a treader. By using this method, you leave the soil firm but with the residue well distributed over the surface to protect the soil against

FIGURE 11.—Alfalfa in foreground was seeded on residue-covered ground. The area enclosed by stakes was seeded on plowed land. Erosion on the plowed land was much more severe than on residue-protected land. Also, more of the stand on the plowed land was lost by winter killing.

either water or wind erosion. It has also been found that less winter killing takes place on residue-covered land than on plowed land. Grass seed that will pass through a drill is best seeded in that manner. Drills with depth regulators on the disks are often used.

Row-Crop Planters

Corn planted on residue-covered ground usually is planted in small furrows in order to make weed eradication easier during cultivation (fig. 12, *B*). Most of the residue is left on the surface between the rows to increase intake of water and to protect the soil against water or wind erosion. Some men surface-plant corn so that there will be no furrow for the water to follow. This has some advantage for erosion control but a decided disadvantage in weed control. If you check-row your row crop this objection will be largely overcome.

There are various ways that you can plant in furrows, but one of the simplest is by means of furrow openers on a standard row-crop planter. If these furrow openers are mounted on stub runners, they will pass through large amounts of residue with little trouble from clogging. By pulling a treader ahead of the planter, you will level the ground and make cultivation easier.

You can use a lister planter with some type of point or small shovel for making furrows and obtain the same advantages as from the furrow openers of a planter. Various tool-bar machines provide different types of shovels that may be used for row-crop planting.

Row crops such as sorghum or soybeans can be planted success-

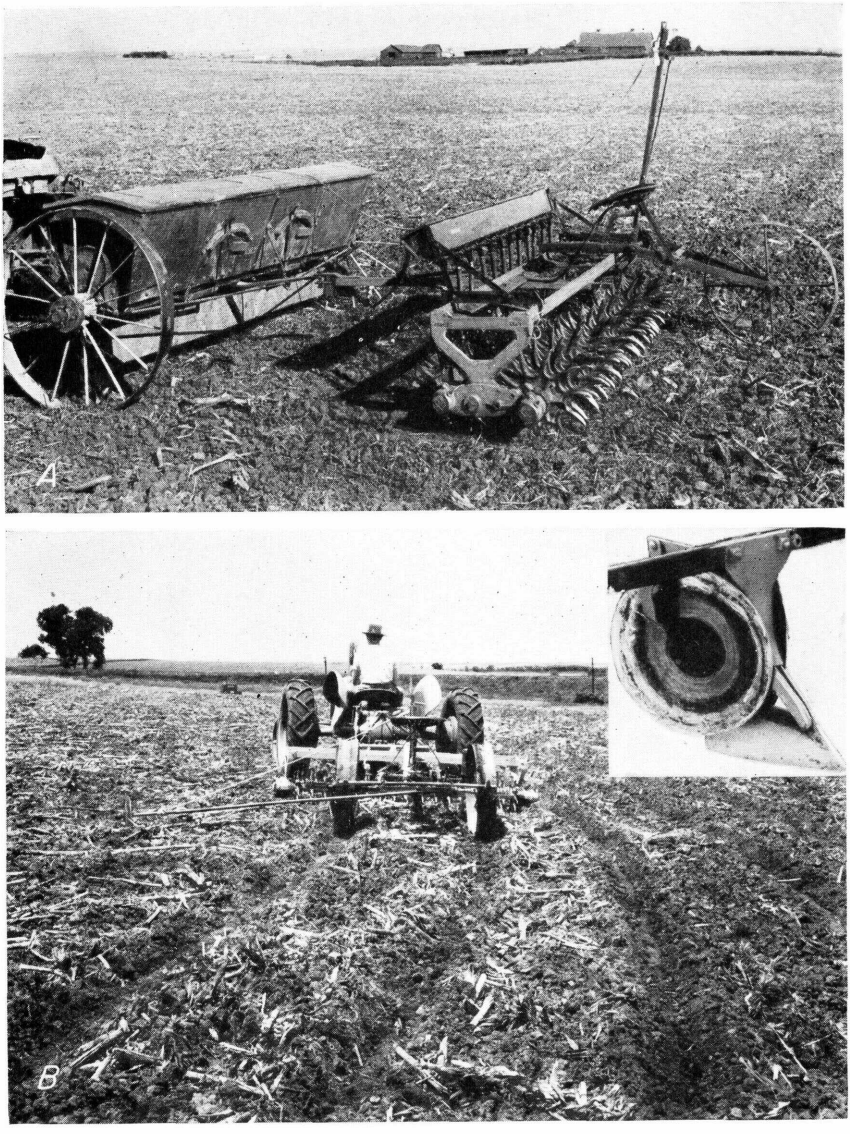

FIGURE 12.—*A*, Seeding a bromegrass and alfalfa mixture on residue-protected land. The bromegrass is seeded through the lime spreader and the alfalfa from the grass seeder attached on front of treader. Both kinds of seed are covered by the treader. *B*, Planting corn on the contour through cornstalk residue. The planter is pulled behind the treader. Insert shows construction of the disk furrow opener and stub runner.

fully by the same methods as indicated for corn. Although soybeans have long been regarded as a crop that may permit increased erosion, soils planted to soybeans have been protected successfully by a good amount of residue.

CULTIVATING ROW CROPS THROUGH STUBBLE MULCH

One of the big advantages you obtain from the use of residues is the protection of land while it is growing cultivated crops. It has already been shown how the seedbed can be prepared and the crop planted while residues are on the land. Your next step is proper cultivation of the row crop. If you are to maintain residue on the surface throughout the growing season, you will have to cultivate beneath the residue. You can do this by using sweep-type cultivators.

If you replace the shovels commonly used on row-crop cultivators with broad sweeps which work beneath the residue and do not bury it, you can maintain much of the protective material on the surface throughout the season. Some of the various types of cultivators are shown in figures 13 and 14.

Where you plant row crops in furrows, your first cultivation should kill most of the weeds in the row. You can usually do this by proper setting of sweeps and disk hillers. For the first cultivation the disk hillers may give best results if you set them to throw soil away from the row. This cuts the soil along the edge of the furrow and it is pushed back again by the heel of the sweep that follows. Thus you give the soil along the row a thorough working and cover the weeds.

Machinery companies are just beginning to consider manufacturing row-crop cultivators designed especially for stubble-mulch farming. In the absence of necessary equipment on the market, some farmers have improvised their own row-crop cultivators to use in stubble-mulch farming.

You can convert many horse-drawn cultivators, either one- or two-rows into sweep-type machines. This may require new or reinforced beams, which can be made in any good farm shop or blacksmith shop.

In a similar manner, you can place sweeps on tractor cultivators (fig. 14, *B*). They may be attached to the regular shanks, but care must be taken that the shanks are tight and that the sweeps have very narrow tongues for attachment, so that they will not make furrows or bury the residue.

Another type of cultivator uses the same principle but is mounted on the rear of a tractor. A single sweep is used in the middle, which cultivates the middle between the parallel rows planted with a two-row. Small sweeps are used on the outside. These must be wide enough to completely cover the middle in two trips (fig. 14, *A*).

On all these machines disk hillers are used to supplement the action of the sweeps. You can attach these to a crossbar between the beams. These disks can be used as shields to prevent covering the young plants. They can be locked in position so they will throw some soil from the bottom of the furrow away from the corn. The soil is then rolled

FIGURE 13.—*A*, Single-row cultivator equipped with two 22-inch sweeps. Rolling coulters that can be locked in position are used as shields. *B*, Two-row, pull-type cultivator equipped with one 32-inch sweep in middle for operating between the parallel rows made with a two-row planter. A 20–22-inch sweep on the outside of each row gives complete ground coverage.

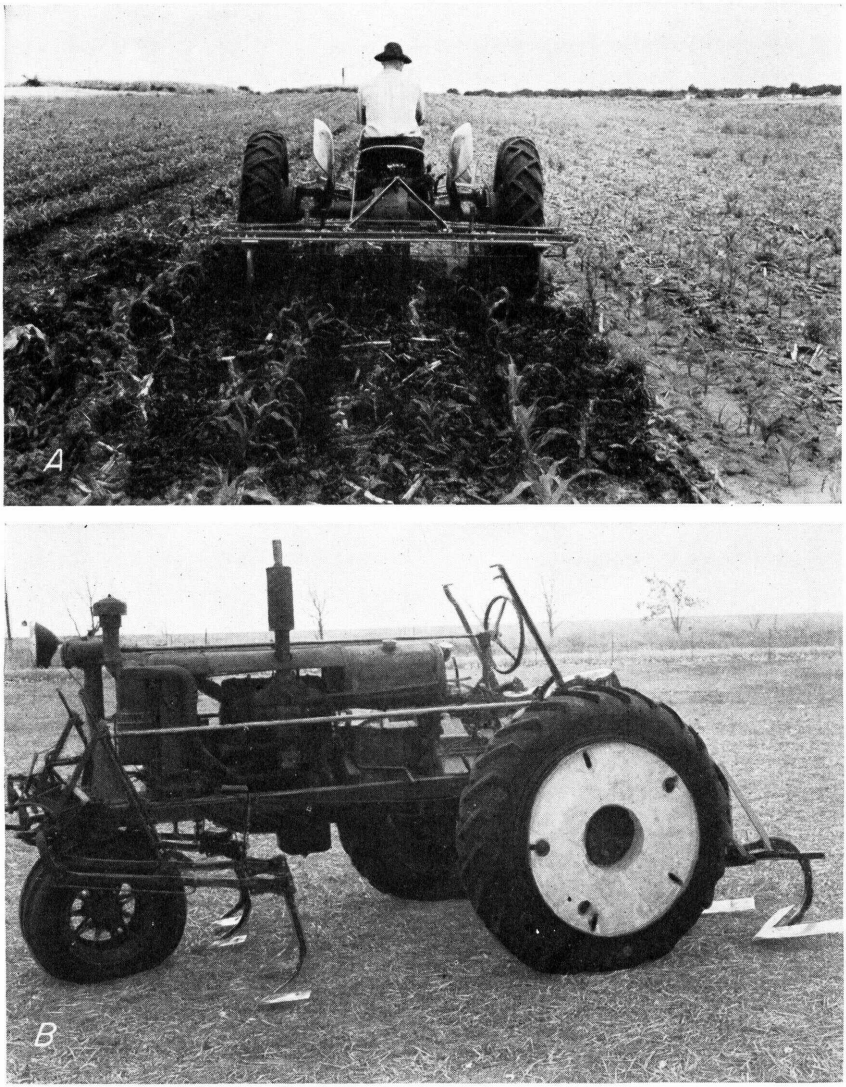

FIGURE. 14.—*A*, A two-row cultivator attached to a hydraulic system on the rear of a tractor. The middle sweep is 32 inches wide; the outside sweep, 22 inches. Disks are throwing soil away from corn at first cultivation. Loosened soil is pushed back around corn by the wing of the V-sweep. *B*, A farmer-built, tractor-mounted, sweep-type cultivator. Twelve-inch sweeps are used in front. Larger sweeps attached in rear cultivate middles and eliminate wheel tracks.

back from the wing of the sweep. In this way you can get effective weed eradication. As the corn gets larger, often at the second cultivation, it is more satisfactory to use the curved-disk hillers set to throw some soil toward the row. They are more effective in covering weeds in the row especially at the last cultivation if the disks do not stand

exactly opposite, but are set so that one is a few inches ahead of the other.

YIELDS OF CROPS ON STUBBLE-MULCH LAND

The yields of crops under a system of crop residues have been measured at the Nebraska station during years of low rainfall (1939–1941) and during years of above-normal rainfall since 1942. The yields during the drier years were higher on the land protected by residue, owing undoubtedly to greater conservation of water in the soil. During the wet years the soil was filled with moisture at the beginning of the season, and water did not become a limiting factor during the growth of the crop. As a result, the yields have been slightly higher during the wet years from the plowed land.

TABLE 2.—*Yields on land farmed with and without residues in a grain rotation of corn, oats, wheat, 1939–44*

Crop	Yield per acre		
	Residue removed, land plowed	Residue plowed under	Residue on surface, land subtilled
	Bushels	*Bushels*	*Bushels*
Corn, 1939–41 (3 dry years)	16. 3	18. 7	31. 1
Corn, 1942–44 (3 wet years)	70. 6	73. 7	62. 2
Corn, 1939–44 (3 dry and 3 wet years)	43. 4	46. 2	46. 6
Wheat, 1939–44	23. 4	28. 1	26. 7
Oats, 1940–45	47. 4	51. 2	48. 1

During the three dry years, 1939–1941, the mean yield of corn on land where residues were removed was 16.3 bushels; where the residue was plowed under, 18.7 bushels; and where the residue was left on the surface and land subtilled, 31.1 bushels per acre (table 2). During the next three wet years the yields from these plots were 70.6, 73.7, and 62.2 bushels, respectively. Thus, land with residue left on the surface seems likely to give increases in yields over plowed land during dry years or, possibly, in regions of low rainfall. During wet years or in regions of high rainfall, the greatest benefit of residue may come from reduction in erosion.

There seems to be less advantage to be gained from residues on the oat crop than from residues on wheat and corn (table 2). As a rule, oats in much of the country are seeded on cornland, where the cornstalks are disked down and the oats broadcast or drilled. The greatest part of the cornstalks are left on the surface, even by this method, and serve to protect the land.

Soybeans can be produced satisfactorily under a system of residue protection. As a rule, this crop does not leave much residue and therefore excessive erosion results. It has been found possible to grow soy-

beans under residue cover from the previous crop with much less damage from erosion than where the land has been plowed. Both small-grain residue and cornstalks have been used as residue cover for soybeans. If you cut coarse residue like cornstalks with a stalk cutter and break it with a treader, you will have no trouble in cultivating the beans with sweep-type cultivators. You can destroy the weeds better, however, if you plant the beans in small furrows. The yields of beans during 4 years of tests have been about the same on subtilled and plowed land.

The work with soybeans has indicated that this crop has been grown on rolling land with much less damage from erosion where crop residue is left than where the land is plowed. In brief, the crop could be extended through the use of stubble mulches to somewhat more rolling land with no more danger from erosion than is met with on more moderate slopes when plowed.

COST OF STUBBLE-MULCH FARMING

The cost of farming with residues cover on the land is usually no greater, and occasionally is considerably less than when land is plowed. The power required to pull a subsurface tiller is roughly two-thirds as much as for a plow when the implement cut the same width and depth. When you operate a tiller at a shallow depth, the draft is about like that of a tandem disk harrow.

Except when it is necessary to go over the land an additional time with a tiller or weeder to kill weeds, the subtillage method is distinctly less expensive than plowing, disking, and harrowing. Whether this extra tillage is necessary will depend on the season and previous efforts at weed eradication. As an average, the cost has been slightly less than plowing but slightly more than listing. Against this, however, one must consider the very great advantage for soil and water conservation of subtillage with residues over listing.

LIMITATIONS ON THE USE OF STUBBLE-MULCH FARMING

At present stubble-mulch farming appears to be better adapted to some sections of the country than to others. The method conserves both soil and water. It is, therefore, particularly useful in areas of low rainfall or in areas where torrential rains may cause severe erosion. It is also useful where soil blowing often destroys crops and damages the soil itself. In areas that are apt to get too little rainfall it is important to save as much water as possible from every large rain. Residues on the surface aid in doing this.

Areas that have high rainfall frequently have long wet spells. Then the effects of residue in cutting down runoff and evaporation may be a disadvantage even though the cover at the same time reduces soil

erosion. In these areas it may be desirable to use stubble mulching only through part of the season.

The implements usually used in stubble-mulch farming also make it better adapted to some sections. The large sweeps and rod-weeder attachments and the wide machines are well suited to flat or gently rolling land. Such land is found throughout the Great Plains.

Stubble-mulch farming is not limited to the production of any particular crop. It is, however, most easily used in producing winter or spring wheat or in summer fallowing. The Great Plains, the Pacific Northwest, and the prairie Provinces of Canada, are, therefore, well adapted to stubble-mulch farming. As has been shown, it is readily applied to row crops such as corn, sorghum, soybeans, and in the preparation of seedbeds for legumes and grasses. Research is in progress to determine climatic, soil, and farming conditions under which this system may be most satisfactorily used as a part of a broad soil and moisture conservation program.

MAINTAINING FERTILITY

In stubble-mulch experiments in Nebraska the most satisfactory results have been obtained where the soil has been kept highly fertile. There is a tendency, where straw or stalk residues are used, for the nitrate content of stubble-mulched land to run slightly lower than that of plowed land. Therefore, if soil conditions are not favorable for nitrate production, the stubble-mulched land may be at a disadvantage. On the other hand, if legumes are used in the rotation, there is usually a good supply of nitrate even with residue left on the surface. Under these conditions good yields have been obtained. It seems, therefore, that on poor land where nothing is being done to keep up the active fertility, plowing may give the higher yields. But if good farming is being done, under conditions such as we have in Nebraska, as high yields are obtained with stubble-mulch farming as with plowing. Also, under the stubble-mulch system the land is under much greater protection against runoff and erosion at all times. For this reason its fertility will be better maintained over a period of years.

During these experiments the physical condition or tilth of the soil has also remained as good or better under the stubble-mulch system as under plowing.

USE WITH OTHER CONSERVATION PRACTICES

If you are considering using stubble-mulch farming to aid in protecting your soil, you must not think of it as complete in itself. It should be used along with other well-established soil conservation

practices. You must use it as an addition to and not as a substitute for such conservation practices as crop rotations, contour farming, terracing, or keeping rough land or waterways in grass. You must fit it into its proper place in a fully developed conservation program. If you do this properly, it can be made to serve as a long step forward in the complete and continuous protection of our cultivated land against water and soil losses.

FIGURE 15.—Residue protects land against wind erosion. *A*, Land that was plowed in the fall and seeded to grass in the spring. The seed was covered with a roller and the surface left fine and smooth. Severe wind erosion followed. *B*, An adjoining field during the same storm. This field was also recently seeded, but it was protected by residue. There is no wind erosion here.

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